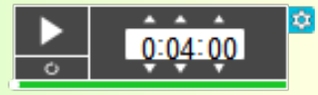
Electric fields	**Electric fields and Coulomb's Law**

Learning objectives	**MUST (C)**	Define an electric field, and explain how it is shown diagrammatically
	SHOULD (B)	Recall and apply the equation for electric field strength
	COULD (A/A*)	Apply Coulomb's Law

STARTER: As accurately as you can, write a definition of an electric field. How would you know if an electric field was associated with an object?

EXTENSION: Compare and contrast electric fields with magnetic fields and/or gravitational fields.



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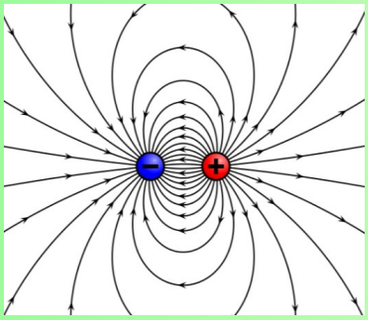
Electric fields	**Electric fields and Coulomb's Law**
MUST (C)	Define an electric field, and explain how it is shown diagrammatically

An electric field is created by a charged object, and other charged objects in this field will experience a force.

(Like charges repel - unlike charges attract)

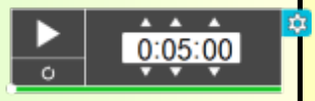
What are the rules about showing electric field in a diagram?



Arrows point away from positive charge, towards negative. At any point on the diagram, the arrow will point in the direction in which a positively-charged object would move.

Closer lines - stronger field

Lines are always at right angles to the surface of a conductor



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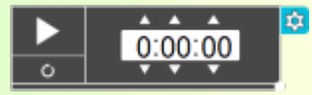
Electric fields	**Electric fields and Coulomb's Law**
SHOULD (B)	Recall and apply the equation for electric field strength

Electric field strength is defined as the force experienced per unit positive charge at that point.

Electric field strength, *E,* at a point where a positive charge *Q* experiences a force *F*:

$$E = \frac{F}{Q}$$

What are the units of electric field strength? NC^{-1}



Calculate the force on an electron in an electric field of strength 2000 NC^{-1}.

Ext: What is its acceleration?

E = F/Q, so rearrange to give F = EQ.

F = 2000 NC^{-1} x 1.602 x 10^{-19} C

F = 3.204 x 10^{-16} N

F = ma, so therefore a = F/m

a = 3.204 x 10^{-16} N/9.109 x 10^{-31} kg

≈ 3.5 x 10^{14} ms^{-2}

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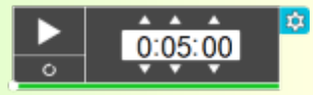
Electric fields	**Electric field strength and Coulomb's Law**
COULD (8/9)	Apply Coulomb's Law

Two point charges are exerting a force on each other. What quantities will determine the amount of force? Will the force be the same? **Ext**: will the quantities be proportional to the force?

Coulomb's Law

Any two point charges exert an electrostatic force on each other that is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$$



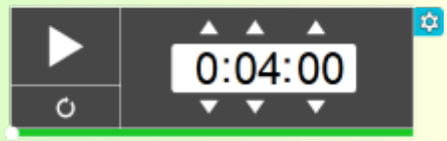
ε_0 = 8.85 x 10^{-12} Fm^{-1}, and is the permittivity of free space

Coulomb's law can be used with large uniformly charged spheres: r is the distance to the centre of the sphere.

Radial fields: finding the electric field strength at a distance from a charge

For the electric field strength at a distance *r* from a point with a charge +Q, you use Coulomb's law. Imagine a test charge with positive charge *q* at a distance *r* from the point.

The force is: $F = \frac{Qq}{4\pi\varepsilon_0 r^2}$

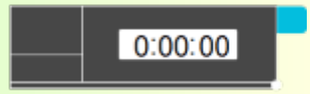


We know that E = F/q, so therefore: $E = \frac{F}{q} = \frac{Qq}{4\pi\varepsilon_0 r^2 q}$

The q's cancel out to leave: $E = \frac{Q}{4\pi\varepsilon_0 r^2}$

Electric fields	**Electric field strength and Coulomb's Law**
COULD (8/9)	Apply Coulomb's Law

A proton and an electron are initially separated by a distance *d*.



Calculate the magnitude of the force between them, if *d* is 5.29 x 10^{-11} m.

ε_0 = 8.85 x 10^{-12} Fm^{-1}

Extension: they are released simultaneously and are free to move. When they collide, are they a) closer to the electron's initial position, b) closer to the proton's initial position, or c) exactly at the midpoint? Explain your answer.

Further extension: When released, will their speed be constant? Will their acceleration be constant? Explain your answer.

$$F = \frac{Qq}{4\pi\varepsilon_0 r^2} \qquad F = \frac{-1.602\times10^{-19}\times1.602\times10^{-19}}{4\times\pi\times8.85\times10^{-12}\times(5.29\times10^{-11})^2}$$

=8.246x10^{-8} N

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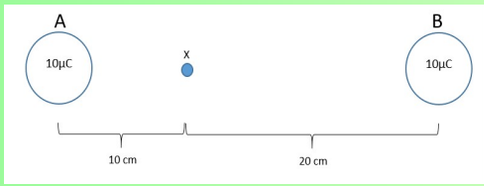
Electric fields	**Electric field strength and Coulomb's Law**
COULD (8/9)	Apply Coulomb's Law

Two charges of 10 μC are separated by 30 cm. Show that the electric field strength at point X, which is 10 cm away from A and 20 cm away from B, is approximately 6.75 x 10^6 NC^{-1}



$$E = \frac{Q}{4\pi\varepsilon_0 r^2}$$

Hint: We need to use the equation for the radial field strength at a distance from a charge.
ε_0 = 8.85 x 10^{-12} Fm^{-1}

There are two fields acting on X: the one from A, to the right, and the one from B, to the left. The resultant will be (Field strength due to A - Field strength due to B)

Field strength due to A:

$$E = \frac{10 \times 10^{-6}}{4\pi \times 8.85 \times 10^{-12} \times 0.1^2}$$

≈ 9.0 x 10^{-6} NC^{-1}

Field strength due to B:

$$E = \frac{10 \times 10^{-6}}{4\pi \times 8.85 \times 10^{-12} \times 0.2^2}$$

≈ 2.25 x 10^{-6} NC^{-1} so overall field is (9.0 - 2.25) = 6.75 x 10^{-6} NC^{-1}

[redacted]

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PLENARY: Answer the question below and explain in full.

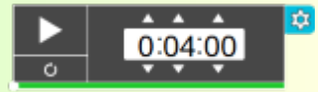
A repulsive force *F* acts between two positive point charges separated by a distance *r*.
What will be the force between them if each charge is doubled and the distance between them is halved?

A *F*

B 2*F*

C 4*F*

D 16*F*



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